Claims

[c1] A method for characterizing a formation, the method comprising:

exciting the formation with an acoustic wave propagating into the formation (61);

measuring a seismo-electromagnetic signal produced by the acoustic wave within the formation (62);

exciting the formation with an electromagnetic exciting field (64);

measuring an electromagneto-seismic signal produced by the electromagnetic exciting field within the formation (65);

analyzing the measured seismo-electromagnetic signal and the measured electromagneto-seismic signal to evaluate characterizing parameters of the formation (69).

[c2] The method of claim 1, wherein

the acoustic wave (408) and the electromagnetic exciting field (411) are generated at a logging tool (407; 507) positioned within a borehole (402; 502) surrounded by the formation (401; 501).

[c3] The method of claim 1 or 2, further comprising:

measuring an acoustic response signal, the acoustic response signal being produced by the acoustic exciting (63);

estimating acoustic properties of the formation from the acoustic response signal (67);

measuring an electromagnetic response signal, the electromagnetic response signal being produced by the electromagnetic exciting (66);

estimating electromagnetic properties of the formation from the electromagnetic response signal (68).

[c4] The method of claim 3, further comprising:

selecting initial values of inversion parameters (71);

synthesizing a synthesis seismo-electromagnetic signal and a synthesis electromagneto-seismic signal using the initial values of the inversion parameters (72);

calculating a first difference between the synthesis seismo-electromagnetic signal and the measured seismo-electromagnetic signal;

calculating a second difference between the synthesis electromagneto-seismic signal and the measured electromagneto-seismic signal (73);

adjusting the values of the inversion parameters according to the first difference and to the second difference (75);

repeating the synthesizing using the adjusted values of the inversion parameters, the calculating of the first difference, the calculating of the second difference and the adjusting until the first difference and the second difference respectively drop below a first predetermined threshold and a second predetermined threshold.

[c5] The method of claim 4, wherein :

the inversion parameters are an electrokinetic coupling coefficient and a mobility;

the synthesizing is simplified by synthesizing only a synthesis seismo-electromagnetic slow longitudinal signal and a synthesis electromagneto-seismic slow longitudinal signal from a mobility initial value and from an electrokinetic coupling coefficient initial value.

[c6] The method according to any one of claims 1 to 5, wherein

the analyzing takes into consideration the propagating of the acoustic wave (408) within the formation (401).

[c7] The method according to any one of claims 1 to 6, wherein :

the seismo-electromagnetic signal (409) is a seismo-electric signal.

[c8] The method according to any one of claims 1 to 6, wherein :

the seismo-electromagnetic (409) signal is a seismo-magnetic signal.

[e9] The method according to any one of claims 1 to 8, wherein
the electromagneto-seismic signal (413) is a magneto-seismic signal.

[e10] The method according to any one of claims 1 to 8, wherein
the electromagneto-seismic signal (413) is an electro-seismic signal.

[e11] The method according to any one of claims 2 to 10, further comprising:
displacing the logging tool (407; 507) along the borehole (402; 502) so as to provide a continuous characterizing of the formation (401; 501) as a function of depth.

[e12] A system for characterizing a formation (401) surrounding a borehole (402), the system comprising:
a logging tool (407) to be lowered into the borehole;
an acoustic emitter (403) located onto the logging tool, the acoustic emitter allowing to excite the formation with an acoustic wave (408) propagating within the formation;
an electromagnetic receiver (404) to measure a seismo-electromagnetic signal (409) produced by the acoustic wave within the formation;
an electromagnetic emitter (404) located onto the logging tool, the electromagnetic emitter allowing to excite the formation with an electromagnetic exciting field (411);
an acoustic receiver (403) to measure a electromagneto-seismic signal (413) produced by the electromagnetic exciting field within the formation;
processing means (414) to analyze the measured seismo-electromagnetic signal and the measured electromagneto-seismic signal so as to evaluate characterizing parameters of the formation.

[c13] The system of claim 12, wherein :

the electromagnetic receiver (404) is an electric receiver allowing to measure a seismo-electric signal (409) produced by the acoustic wave (408) within the formation (401).

[c14] The system of claim 12, wherein :

the electromagnetic receiver (504) is a magnetic receiver allowing to measure a seismo-magnetic signal produced by the acoustic wave within the formation (501).

[c15] The system of any one of claims 12 to 14, wherein :

the electromagnetic emitter (404) is an electric emitter allowing excite the formation (401) with an electric exciting field.

[c16] The system of any one of claims 12 to 14, wherein :

the electromagnetic emitter (504) is a magnetic emitter allowing excite the formation (501) with a magnetic exciting field.

[c17] The system of claim 12, or 13, further comprising:

At least one additional electromagnetic receiver (506);

At least one additional acoustic receiver (505).